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half-surface of a sphere (not a hemisphere in the ordinary sense of the word, for there is great advantage in employing a different form of boundary)—viz., there is an *e*-spherogram, showing the iseccentric lines; and a T-spherogram showing the isochronic lines.

On the application of Photography as a means of determining the Solar Parallax from the Transit of Venus in 1874. By Richard A. Proctor, B.A.

It is impossible to read Mr. De La Rue's account of the results of careful measurement applied to photographs of the solar eclipses in 1860 and 1868 without recognising that we have in photography, as applied to the approaching Transit of *Venus*, one of the most powerful available means of determining the Sun's distance. Within the last few years, solar photography has made a progress which is very promising in regard to the future achievements of the science as an aid to exact astronomy. So that doubtless, in 1874, astronomers will apply photographic methods to the transit of that year, with even greater success than we should now be prepared to anticipate. It has therefore seemed to me that the photographic observation of the coming transit merits at least as full a preliminary inquiry as either Halley's or Delisle's method of direct observation.

The result of an inquiry directed to this end has led me to the conclusion that photographers of the approaching transit should adopt for their guidance considerations somewhat different than those which have hitherto been chiefly attended to.

It is undoubtedly true, as Mr. De La Rue has pointed out, that the photographer of the transit can readily take a large number of pictures, and by combining these, can ascertain with great accuracy the path of *Venus* across the solar disc. And by comparing the paths thus deduced for different stations a satisfactory estimate can be formed of the solar parallax. I do not wish to suggest any departure from this course of procedure.

On the other hand, it is undoubtedly true, as Major Tennant has remarked, that the greatest effect of parallax will be obtained for any two stations, when both stations, the Earth's centre, and the centre of *Venus*, are in one and the same plane. So far as those two stations are concerned, his remark is just, that it is the position of *Venus* at the instant when the stations are so situated, and not the nearest approach of *Venus* to the Sun's centre, which should be compared. And further, Mr. De La Rue's comment on this, to the effect that his method in reality includes Major Tennant's, is also correct. In fact, there can be no doubt that the position of *Venus* at the particular instant referred to by Major Tennant can be far more exactly ascertained by a reference to the complete path of *Venus* for each station than from any attempt to secure nearly simultaneous photographic records at stations far removed from each other.

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But it appears to me that the method I am about to suggest, according to which the whole question will be reduced to the determination of a parallactic displacement of *Venus* on a line through the centre of the Sun's disc, is the one by which the fullest assistance will be obtained from photography; while a source of error, which has not hitherto been specially considered, will be practically eliminated.

It must be remembered that in the comparison of photographic records, whether for the determination of the path of *Venus* across the Sun's disc at a particular station, or for the comparison either of *Venus's* apparent position or of her path as seen from two different stations, the accuracy of the results will depend in part on the certainty with which two or more pictures may be brought into comparison by means of a fiducial line or set of lines. It seems certain that no method can be devised by which all chance of error from this source can be eliminated. The great point would, therefore, seem to be to render its effect as small as possible.

Now let us consider for a moment Major Tennant's proposition, as giving a convenient illustration of the effects of any error either in the position of the fiducial lines, or in bringing those belonging to two pictures into exact correspondence. Let Fig. 1 represent the result of a comparison between two photographs of the Sun. A B and C D are fiducial cross-lines common to both pictures, *a* is the centre of *Venus* for one picture, *b* is her centre for the other; and on the exact measurement of *a b* depends the determination of the Sun's parallax, so far at least as these two pictures are concerned. Now it is very obvious that if the lines A B, C D for one picture, have not been brought into perfect correspondence with those belonging to the other, the distance *a b* will be correspondingly affected. In fact, it would appear that if the usual methods for making the correspondence as exact as possible are followed, almost as large an error would be introduced through this cause alone as by errors in the measurement of *a b*, since the two processes—the measurement of *a b* and the adjustment of the sets of cross-lines—depend on the very same circumstance, the nicety, namely, with which the eye and the judgment can estimate minute quantities of about the same relative dimensions.

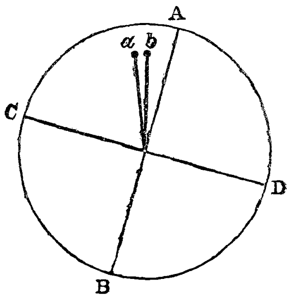

Fig. 1.

But now, if *a* and *b*, in place of having the position shown in Fig. 1, were situated as in Fig. 2, it is clear that the distance *a b* will not be appreciably affected by any small error in the adjustment of the fiducial lines.

The object, therefore, which it seems most desirable to secure is that *Venus*, as seen from two different stations at a particular instant, should have a relative parallactic displacement towards

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the Sun's centre, or as nearly towards the Sun's centre as possible. This amounts to adding to Major Tennant's conditions this further one that the Sun's centre should be in the same plane with the two stations,—or rather to making this condition a substitute for that one which requires that the Earth's centre should be in the same plane with the two stations. For as a rule we must not expect to be able to secure that two convenient stations on the Earth, as well as the centres of the Earth, *Venus*, and the Sun, should be in the same plane.

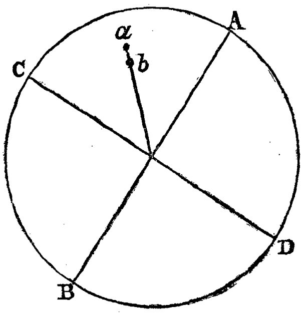

Fig. 2.

Mr. De La Rue's remark that by taking a series of pictures the position of *Venus* may be ascertained at any moment is in reality quite as applicable to my suggestion as to Major Tennant's. In fact, were it not, we might despair of securing the desired object, since we have no reason for believing that astronomers are so certain as to the exact progress of the transit, that the conditions could be secured by anticipatory instructions: whereas by applying Mr. De La Rue's method it will be possible after the transit is past, to determine with any desired degree of accuracy the position of *Venus* at the proper instant. And further, it is very obvious that no error in the placing of the fiducial lines for pictures taken at the same stations can much affect the accuracy of the result, since the comparison of successive pictures, taken at the same station, does not directly involve the element of the solar parallax, as when we have to compare two pictures or paths determined at different stations.

The object, then, of the present paper and the accompanying chart is to determine what stations are most suitable for applying photography to the transit of 1874, on the principles above enumerated. I think the drawing will be found, however, to be also an instructive illustration of the whole character of the transit.

In a paper in the *Monthly Notices* for March last, I showed how all the chief elements of the transit could be deduced by considering the motion of *Venus* relatively to a pair of cones, each enveloping the Sun and the Earth, but one having its vertex outside the Earth, the other having its vertex between the Earth and the Sun. For my present purpose it will be convenient to con-

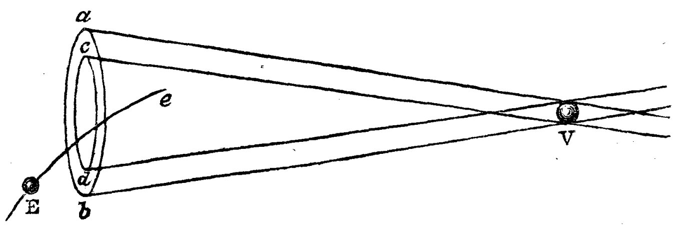

Fig. 3.

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sider the motion of the Earth relatively to a pair of cones similarly enveloping the Sun and *Venus*.

Fig. 3 represents a portion of these cones around *Venus* at V. E *e* is the Earth's orbit relatively to these cones; *a b* is the circular section of the outer cone, *c d* that of the inner. *Venus* is supposed to be approaching the eye, and therefore the Earth also would, at the time of conjunction, be approaching; but as we are considering the Earth's motion relatively to the two cones, and as *Venus* moves more rapidly in her orbit than the Earth, we must suppose the Earth to traverse the sections *a b* and *c d* in direction E *e*. When the circumstances of the transit of 1874 are attended to, it results that the motion of the Earth relatively to the sections *a b* and *c d* is as shown in Fig. 4. The various circles represented along the parallels E *e* correspond to the various positions of the Earth represented in the illustrative plate.

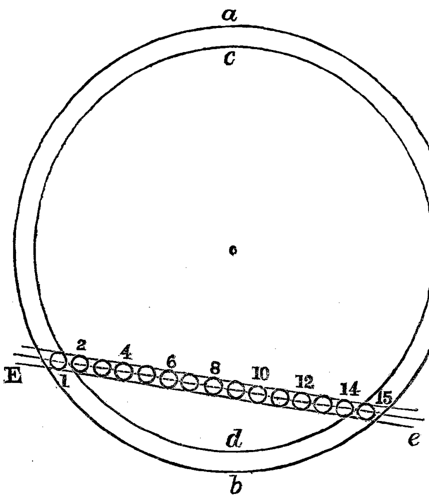

Fig. 4.

Comparing Figs. 3 and 4, it will be seen at once that as soon as the Earth reaches the outer circle *a b*, external contact begins. With the peculiarities of this phase, we need not concern ourselves. When the Earth reaches the circle *c d*, as at position 1, Fig. 4, internal contact begins, and when the Earth just touches the circle *c d* on the inside, the transit has begun for all places on the Earth's illuminated hemisphere. The positions 1 and 2 correspond to the cases of internal contact most accelerated and internal contact most retarded. They have been added to the illustrative plate for the sake of completeness, but in reality they do not belong to the special subject of this paper, since, as Mr. De La Rue has remarked, the photographer need not set himself to observe special phases of this sort. The same remark applies to the positions 14 and 15.

The remaining positions of the Earth in Fig. 4, corresponding to the 11 pictures 3–13 in the illustrative plate, are those occupied by the Earth at successive intervals of 15 minutes, the picture numbered 8 corresponding to the position occupied by the Earth at $16^{h}\ 6^{m}\ 31^{s}$ G.M.T., on Dec. 28th 1874, when *Venus* makes her nearest approach to the centre of the Sun's disc.

Now if we look at Figs. 3 and 4, and consider what they represent, we shall see that Fig. 4 may be looked upon as exhibiting an inverted picture of the Sun's disc and the transit of *Venus's* centre across it: we see, in fact, that the apparent position occupied at any instant by any point on the Earth's surface

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in Fig. 4, corresponds exactly to the position occupied by *Venus* upon the Sun's disc, as supposed to be seen from that point of the Earth's surface at the instant in question. We have only to invert Fig. 4, and look at it from behind to see what sort of path *Venus* would seem to traverse upon the Sun's disc, either with reference to the Earth's centre, or to any point of the Earth's surface supposed to be properly depicted upon the small figures 1—15.

It follows, therefore, that if we want to determine two stations at which at any instant *Venus* would appear to have a relative parallactic displacement towards the Sun's centre, all that is required is that we select two stations which are on the same radial line from the common centre of the circular sections *a b* and *c d*.

The positions of those radial lines which cross the Earth's track through the section *c d* are exhibited in the plate. It will be understood, of course, that the three rows of figures belong in reality to a single row, the numbering of the successive pictures of the Earth indicating the way in which that row would be formed by the combination of the three rows shown in the plate.

I need not explain the construction of the plate, which depends on the simplest mathematical principles. I have taken a considerable amount of care to secure accuracy, not only in the projections of the Earth, but in the position of the radial cross-lines; and, though there may be minute inexactnesses, there will be found none, I think, which affect the purpose for which the plate was constructed. What that purpose is, will be best illustrated by simply examining the indications of the successive pictures.

Passing over pictures 1 and 2, we notice in Fig. 3, that Kerguelen's Land and Crozet Island, lying nearly on a line with certain of the Aleutian Islands, suggest that pictures taken at the former stations at the beginning of the transit could be advantageously compared with pictures simultaneously, or almost simultaneously, taken at a station on one of the easternmost of the Aleutians. In like manner pictures taken near Enderby Land could be advantageously compared with pictures taken at Woahoo. Projection 4 does not differ much from the preceding, but the cross-lines have assumed a less inclined position, and Kerguelen's Land could, at the epoch belonging to this picture, be better combined with a somewhat more westerly Aleutian island.

Projection 5 exhibits the advantage of a photographic station at or near Yokohama. Probably such a station, combined with one in Crozet Island or Kerguelen's Land, would give (by pictures taken near the hour belonging to Projection 5) absolutely the best results which photography can give.

The remaining projections suggest the following combinations of photographic records:—

Projection 6. Yokohama and Enderby Land, Kerguelen's Land

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and a station in Manchooria; Crozet Island and Pekin; Cape of Good Hope and Nertchinsk.

Projection 7. Kerguelen's Land and Tsitsikar; Crozet Island and Nertchinsk; Cape Town and a station west of Lake Baikal.

Projection 8. Kerguelen's Land and Nertchinsk; Cape Town and Peshawur; Repulse Bay or neighbourhood and Yokohama; Perth (Australia) and Yokohama.

Projection 9. Repulse Bay and Yokohama; Enderby Land and Nertchinsk; Crozet Island and Calcutta; Cape Town and Bombay.

Projection 10. Repulse Bay and Nertchinsk; Possession Island (near South Victoria Land) and Yokohama; Kerguelen's Land and Calcutta; Crozet Island and Peshawur; Cape Town and Teheran.

Projection 11. Possession Island and Tsitsikar; Repulse Bay and neighbourhood of Lake Baikal; Enderby Land and Calcutta; Kerguelen's Land and Madras; Crozet Island and Peshawur; Cape Town and Aden.

Projection 12. Possession Island and Nertchinsk; Enderby Land and Madras; Kerguelen's Land and Peshawur; Crozet Island and Teheran.

Projection 13. Possession Island and neighbourhood of Lake Baikal; Repulse Bay and Calcutta; a New Zealand station and Yokohama; Hobart Town and a station near the mouth of the Amoor.

From this list we see that Kerguelen's Land and Crozet Island; Peshawur and other Indian stations; and stations in Siberia, are those which give the most favourable opportunities for the application of the photographic method.

Observations of Meteors, Nov. 13–14, 1869, at Santa Barbara, California. Observers, G. Davidson and Mrs. E. Davidson.

Watch was kept in camp for the meteoric shower; the night beautifully clear; Moon ten days old and 4° S. Decl. I was called at $1^h\ 10^m$, up to which time 22 meteors had been seen. The diagram exhibits the numbers noted by two observers up to $3^h\ 43^m$ A.M. After that time watch was kept up for any unusual display, but the numbers gradually diminished. The total number recorded was 556 in $2^h\ 25^m$. Some of the meteors were very brilliant and left persistent trains.

"At $1^h\ 25^m$ a meteor without apparent motion suddenly appeared, and burst in the same position. It was about 2° above and to the left of the bright star in the blade of the Sickle." (S. R. Throckmorton, Jun.)

At $2^h\ 33^m$ I observed a brilliant meteor start from a point above and a little to the left of the pointers; it left a persistent train and disappeared at a point about 9° or 10° above *Polaris*